On spintronic torque effect in multilayer magnetic nanostructures

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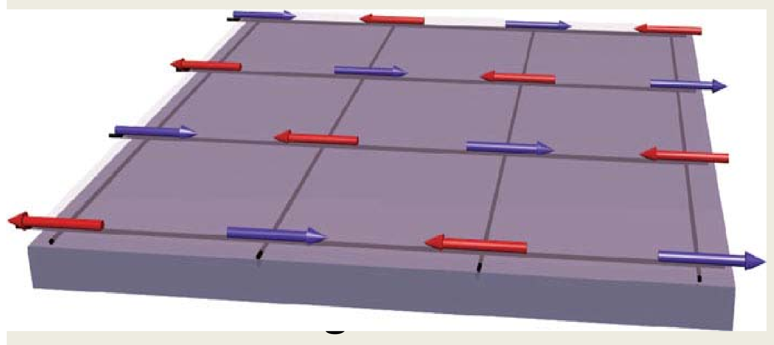
1. Introduction

Spintronics of multilayer magnetic nanostructures is based on the electric control and detection of localized magnetic states via the exchange interaction of the electric-induced spin current with localized magnetic moments. Regardless of the type of the magnetic exchange interaction (ferromagnetic (FM) or antiferromagnetic (AFM)), the impact on the localized magnetic states occurs via the spin torques exerting on the localized magnetic moments. In the FM and AFM cases, these spin torques can result in the FM and AFM order dynamics and switching, respectively. In the case of FM nanostructures it exhibits in the known giant magnetoresistance effect, which was applied for new kinds of field-sensing and magnetic memory devices [1, 2]. The spin torque effectiveness is determined by threshold spin current density for excitation of localized spins due to the nature of spin polarization. The spin polarization can be induced by the effective field of magnetic exchange interaction and magnetic field of spin-orbit interaction related and unrelated to spin polarized electron transport through interface to the localized magnetic states, respectively. The origin of the spin polarization and magnetic exchange interaction between localized magnetic states determines the time and spatial scales of the spin torque effects. The lasts are described in the framework of the microscopic tight-binding model involving the spin-orbit interaction, the interaction between free and localized magnetic states.

2. Methods

The effect of the electric spin-orbit induced torque in AFM nanostructures is described in the framework of model 2D tight-binding spin structure with the exchange interaction of localized spin (H_{dd}), the Rashba spin-orbit interaction of 2D gas of conduction electros(H_R), the tight-binding electron potential (H_{TB}) and the exchange interaction between of current electron spins and the localized spins (H_{SD}). The AFM spin-axis reorientation is manipulated by the applied electric field via Nèel-order spin-orbit torque ***T***, i.e. via nonequilibrium fields that alternate in sign between the two spin sub attices (presented in Fig. 1).



$$H_{dd}= \Sigma J_{dd}\, \mathbf{S}_i \cdot \mathbf{S}_j\,,\quad HR= \Sigma Jsd\, \mathbf{S} \cdot \mathbf{S_j}\,,\quad Hsd= \Sigma Jsd\, \mathbf{S} \cdot \mathbf{S_j}\,, \qquad (1)$$

$$H_R = V_{SO}\, \Sigma_l \left[(C_{i\uparrow}^{+}\, C_{i+\delta x,\downarrow} - C_{\downarrow}^{+}\, C_{i+\delta x,\uparrow}) - i\,[C_{i\uparrow}^{+}\, C_{i+\delta y,\downarrow} - C_{\downarrow}^{+}\, C_{i+\delta y,\uparrow}) + \mathrm{H.c.}\right], \qquad (2)$$

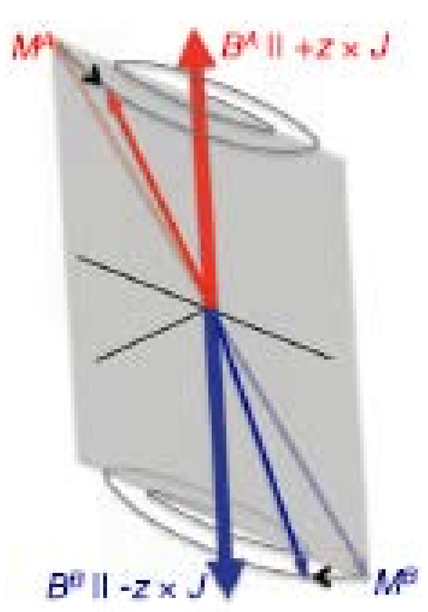
where $C_{i\uparrow}^{+}$ ($C_{i\uparrow}$) is the quantization operator of creation (annihilation) of the electron state at the site *i*

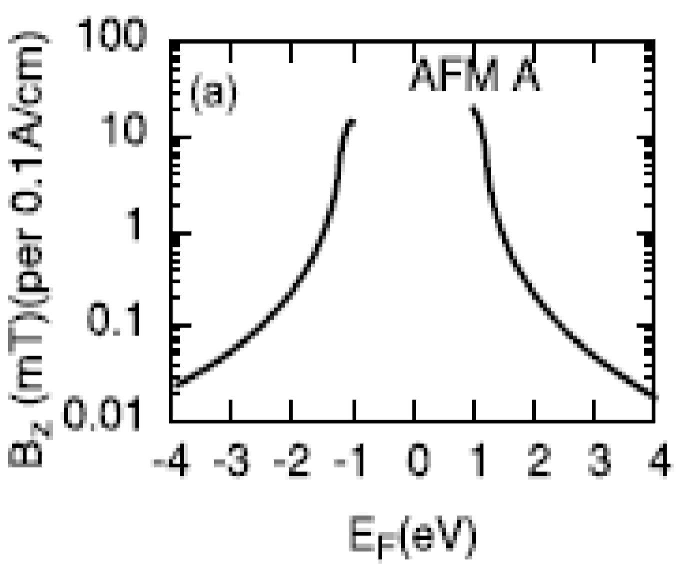
Fig.1. The 2D AFM structure

with a spin $\uparrow$, V_{so} represents the spin-orbit coupling δ_x, and δ_y label the nearest neighbors directions. The analysis of the Hamiltonian (1) is based on the method of non-equilibrium Geen functions of the form

$$G(t,t')=\theta(t,t')\left|G_{ii'}^{>}(t,t')\right|+\theta(t',t)\left|G_{ii'}^{<}(t,t')\right|,\; G_{ii'}^{>}(t,t')=-i\left\langle c_{i\sigma}(t)c_{i'\sigma'}^{\dagger}(t')\right\rangle,\; G_{ii'}^{<}(t,t')=i\left\langle c_{i'\sigma'}^{\dagger}(t')c_{i\sigma}(t)\right\rangle \quad (3)$$

3. Results





A fieldlike torque $T^{A/B} \sim z \times B^{A/B}$ with a staggered $\mathbf{B}^A \sim z \times J$ and $\mathbf{B}^B \sim -z \times J$ can be generated by current in special crystal structures in which the AFM spin sublattices coincide with the two inversion-partner sublattices.

Fig. 2. The z component of the NSOT field in the 2D square-lattice Rashba AFM as a function of the Fermi energy.

Fig. 3.Tthe AFM dynamics in a staggered field generating the fieldlike torque.

Acknowledgment

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References

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